Dear spokesperson,

The Workshop on the Intermediate Neutrino Program (WINP) will be held at Brookhaven National Laboratory on February 4–6, 2015. The workshop organizers request that you fill out the enclosed template for describing your experimental plans by January 12, 2015 at 17:00 EST. These templates will be posted on the public WINP website and are intended to facilitate discussion on the best opportunities for neutrino experiments or R&D that can be accomplished in the intermediate time period (~5–10 years) at reasonable cost. Working group convenors may need input from you on an earlier time scale.

Steve Kettell
For the Organizing Committee

1. Name of Experiment/Project/Collaboration: NuPRISM
2. Physics Goals
    a. Primary: To significantly neutrino interaction uncertainties from long-baseline neutrino oscillation experiments
    b. Secondary: To search for short-baseline sterile neutrino oscillations
    c. Tertiary: To make novel neutrino cross section measurements, such as the first ever measurements of neutral current interactions as a function of neutrino energy
3. Expected location of the experiment/project: J-PARC
4. Neutrino source: J-PARC neutrino beam
5. Primary detector technology: Water Cherenkov
6. Short description of the detector:
   The NuPRISM detector is a tall, narrow version of Super-Kamiokande, designed to span an off-axis angle range from 1°-4° at a distance of 1 km from the T2K neutrino source. By taking linear combinations of measurements from many off-axis angles, and hence many neutrino energy spectra, it is possible to directly measure final state observables for any desired neutrino energy spectra, such as a mono-energetic neutrino beam or the oscillated flux at the far detector for any chosen set of oscillation parameters. By directly measuring oscillated spectra in a near detector, uncertainties from neutrino interaction systematic errors are largely removed. For the first phase of the experiment, a subsection (1/5) of the vertical shaft is instrumented, and the instrumented portion of the detector is occasionally moved vertically through the shaft to sample the full off-axis range.
7. List key publications and/or archive entries describing the project/experiment
    a. Letter of Intent to Construct a NuPRISM Detector in the J-PARC Neutrino Beamline
       S. Bahdra, et al., arXiv:1412.3086 (2014).
8. Collaboration
    a. Institution list:
       University of British Columbia
       University of California, Irvine
       University of Geneva
       High Energy Accelerator Research Organization (KEK)
       Institut de Fisica d’Altes Energies (IFAE, Barcelona)
       Imperial College London

Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
Kavli Institute for the Physics and Mathematics of the Universe (IPMU)
Kyoto University
Michigan State University
Stony Brook University
Osaka University
University of Regina
University of Rochester
STFC, Rutherford Appleton Laboratory
University of Tokyo
University of Tokyo, Institute for Cosmic Ray Research (ICRR)
Tokyo Institute of Technology
University of Toronto
TRIUMF
Warsaw University of Technology
York University
Tokyo Metropolitan University

b. Number of present collaborators: 50

c. Number of collaborators needed:
This detector is expected to be a larger and more complex version of MiniBooNE (75 authors), with a larger physics reach. The optimal size is probably 100-150 collaborators.

9. R&D

  a. List the topics that will be investigated and that have been completed:
  The purpose of NuPRISM is to demonstrate the effectiveness of using a variety of off-axis angle measurements to achieve the aforementioned physics goals.
  NuPRISM is also a fully operational water Cherenkov detector that will be easily accessible for maintenance due to its movement capabilities. The plan is to test a variety of photo-detector technologies within this detector.

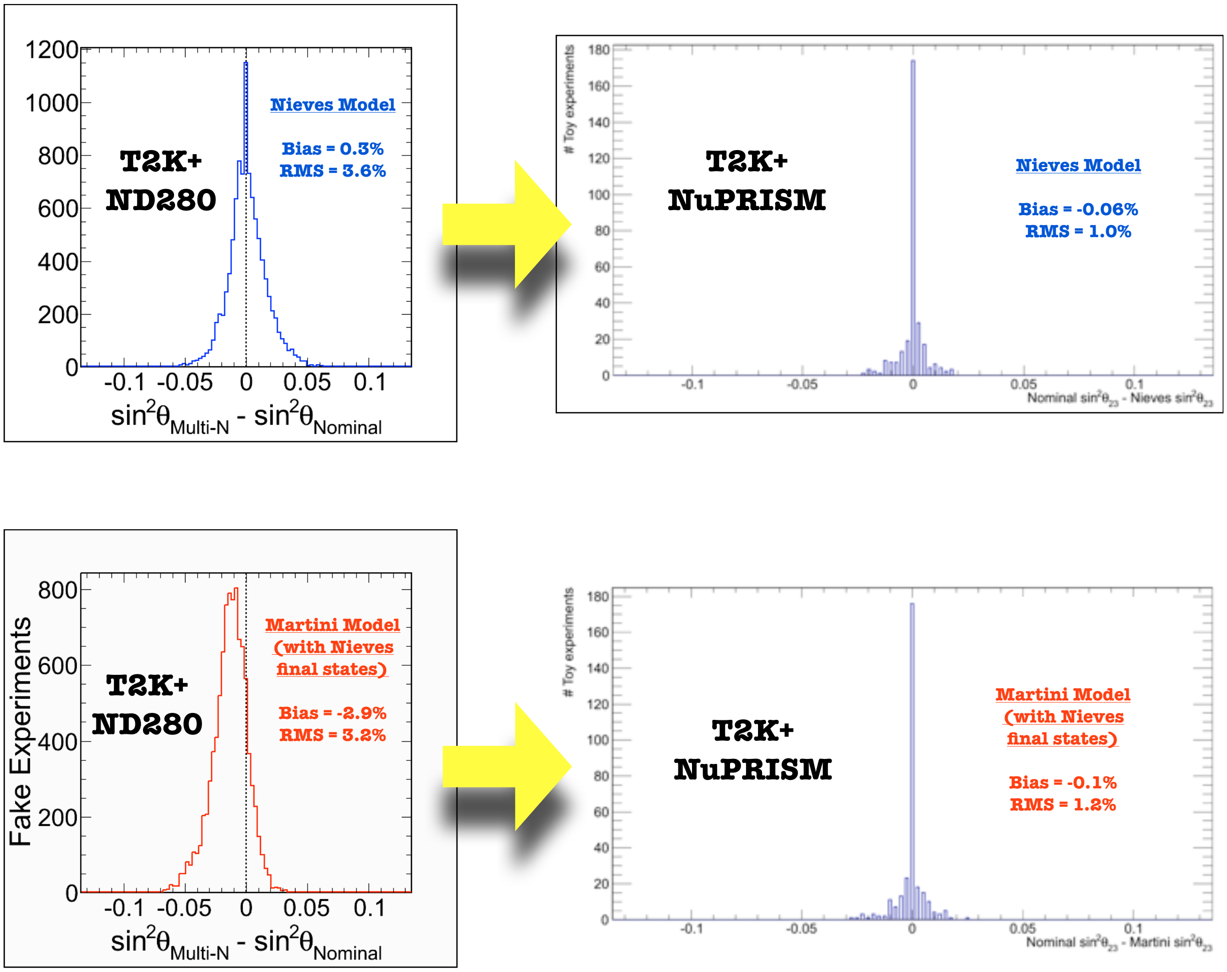
  b. Which of these are crucial to the experiment: The photo-detector R&D is secondary to the physics goals of the experiment.

  c. Timeline: The goal is to begin excavation by the end of 2016

  d. Benefit to future projects:
  All future long-baseline neutrino experiments can benefit from a NuPRISM near detector, and the J-PARC detector will constitute the first proof-of-principle for this concept.

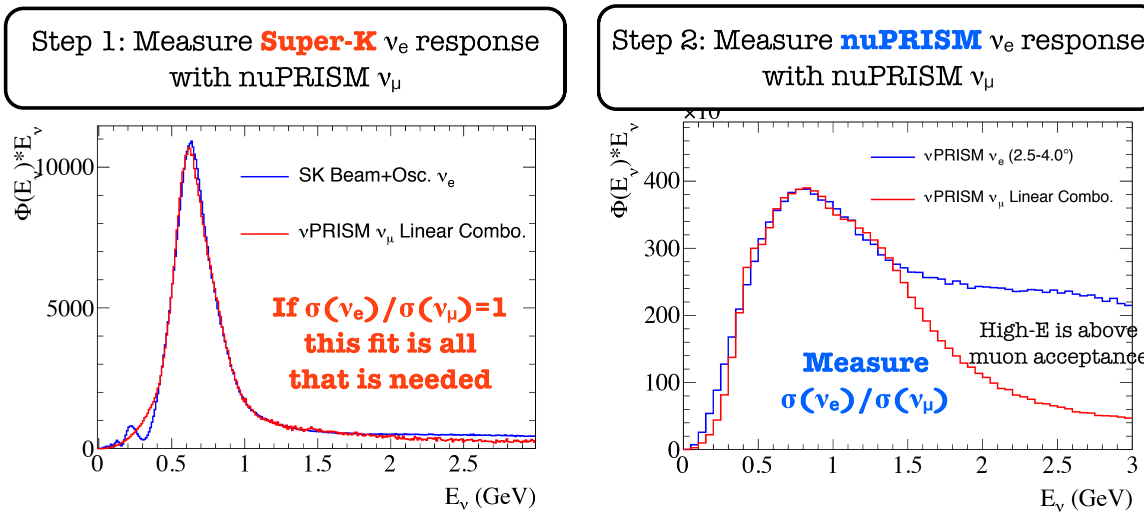
10. Primary physics goal expected results/sensitivity:
The usefulness of the NuPRISM technique has been quantitatively demonstrated in the determination of theta23 via muon neutrino disappearance. The impact of neutrino-nucleus modeling on the T2K experiment has been estimated using the models of Nieves et al. and Martini et al. These models can be compared to the default, single-nucleon models in the neut neutrino interaction generator using fake data sets, which are generated by varying the official T2K flux and cross section systematic errors. In the following figures, the difference in the fitted theta13 value between the default neut single nucleon model and the Nieves or Martini multi-nucleon models is shown for each of the fake data samples. The figures on the left show the result for the default T2K analysis, which uses the current

near detector, ND280, while the figures on the right show the result when ND280 is replaced entirely by NuPRISM.



The systematic uncertainty is characterized by both the RMS and the bias of these distributions. The quadrature sums of these two quantities result in total uncertainties of 3.6% or 4.3% for the Nieves and Martini models, respectively. Additional improvement is expected in the T2K+NuPRISM results when as the additional background constraints that NuPRISM can provide are incorporated into the analysis, and by including information from ND280.

The NuPRISM technique can be extended to other important energy spectra, such as the electron neutrino appearance spectrum, which is used to search for CP violation. NuPRISM uses a two step approach to constrain neutrino interaction uncertainties associated with electron neutrinos. First, linear combinations of NuPRISM muon neutrinos are used to reproduce the oscillated far detector oscillated electron neutrino spectrum. Second, a detailed check of the ν_e/ν_μ cross section ratio in lepton kinematic bins is performed by using taking linear combinations of the NuPRISM ν_μ events to reproduce the NuPRISM ν_e spectrum. An example of both of these fits is shown below. A detailed analysis is underway to quantify the effectiveness of this technique.

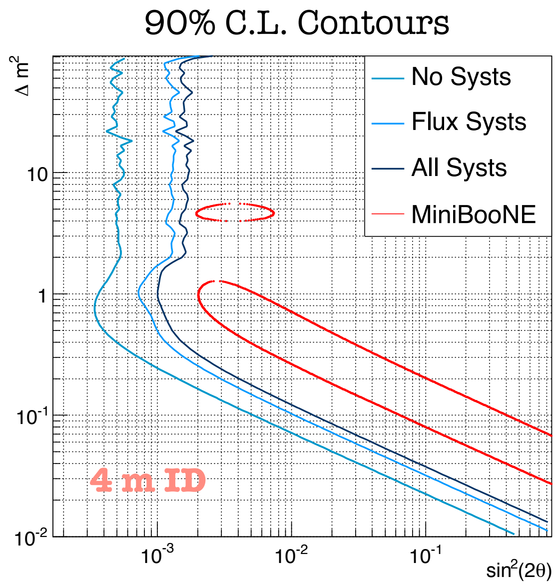


In the cross section ratio measurement (right plot) some disagreement is seen in the energy spectra above 1.5 GeV. However, the impact of this disagreement is expected to be small since (a) the acceptance for muons in NuPRISM falls off between 1 and 1.5 GeV, and (b) the plot shows flux * E_ν in order to approximate the growth of the cross section, but above 1.5 GeV, the cross section for single lepton events does not increase linearly due to the increased frequency of multi-ring events.

a. For exclusion limit (such as sterile neutrino search), show 3-sigma and 5-sigma limits
b. For discovery potential (such as the Mass Hierarchy), show 3-sigma and 5-sigma.
c. For sensitivity plots, show 3-sigma and 5-sigma sensitivities
(note that for neutrino-less double beta decay experiments that have previously been asked for 90% CL and 5 sigma limits these are OK)
d. List the sources of systematic uncertainties included in the above, their magnitudes and the basis for these estimates.
e. List other experiments that have similar physics goals
No other experiment can circumvent neutrino-nucleus interaction uncertainties in a manner that does not depend on the observed interaction final state.
f. Synergies with other experiments.
A NuPRISM near detector can potentially benefit any long-baseline neutrino oscillation experiment.

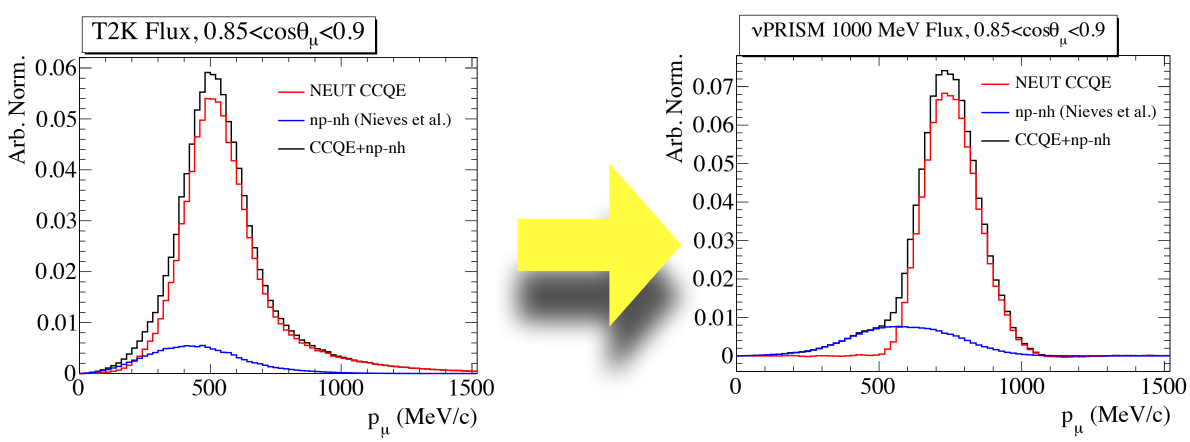
11. Secondary Physics Goal
The NuPRISM sterile neutrino analysis uses a similar approach to that of MiniBooNE, but with two important advantages: (1) NuPRISM samples many different energy spectra (i.e. a continuous variation of L/E), and (2) the existing T2K near detector will provide a near detector constraint for the NuPRISM sterile search.

At present, the NuPRISM sterile neutrino analysis does not yet contain many important inputs: the detector acceptance is overly conservative (Super-K efficiencies with 20” PMTs are currently used), a combined ν_e+ν_μ fit is not yet available (the MiniBooNE measurement would not have been possible without such a fit), the ND280 near detector constraint is not yet implemented, and there are no NuPRISM constraints on any background processes (NuPRISM is expected to provide strong data-driven constraints on most of the important backgrounds).



Despite these overly conservative assumptions, the current NuPRISM analysis still shows sensitivity to sterile neutrino oscillations at the 90% confidence level. Significant improvements in the NuPRISM sterile sensitivity are expected as the aforementioned analysis inputs are implemented.

Finally, NuPRISM will make unique neutrino interaction measurements due to the ability to construct mono-energetic neutrino beams. NuPRISM will provide the first ever measurements of neutral current interactions as a function of neutrino energy, as well as more precise measurements of multi-nucleon effects than is currently possible, as shown in the following figure.



12. Experimental requirements
    a. Provide requirements (neutrino source, intensity, running time, location, space,…) for each physics goal:
       All of the physics goals of NuPRISM can be accomplished in 1 year of full power (750 kW) running at J-PARC. However, J-PARC is expected to run for 2-3 years after the beam is upgraded, and this additional data can further reduce uncertainties on the NuPRISM electron-neutrino measurements. In the nominal schedule, the beam upgrade is scheduled to begin in 2018.
13. Expected Experiment/Project time line

a. Design and development: 1.5 years
b. Construction and Installation: 3 years
c. First data: 2019
d. End of data taking: 2021 or 2022
e. Final results: 2022 or 2023

14. Estimated cost range
    a. US contribution to the experiment/project: $3-5 million. NuPRISM can also make use of previously used MiniBooNE and Daya Bay PMTs as a US contribution to the experiment.
    b. International contribution to the experiment/project: Civil construction and facilities must be provided by KEK/J-PARC, and will require $6-$10 million. A substantial fraction of Hyper-K R&D funds in both Japan and Canada (~$4 million) can also be contributed to NuPRISM.
    c. Operations cost:
       The substantial operations cost for the J-PARC beam is already required for continued running of the T2K experiment. NuPRISM runs parasitically in the same beamline.
15. The Future
    a. Possible detector upgrades and their motivation.
       NuPRISM is being designed to eventually instrument the entire volume, removing the need for a moving instrumented portion. This upgrade would require an additional $12-15 million
    b. Potential avenues this project could open up.
       As stated previously, all future long-baseline neutrino experiments can likely benefit from a NuPRISM near detector, and the J-PARC NuPRISM detector will be the first demonstration that the concept can be successfully implemented.